ON GEOLOGY AND CONSUMPTION.

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On the Connection of the Geological Structure and the Physical Features of the South-East of England, with the Consumption Death-rate.

[A paper read before the Geological Society of London, June 23, 1869.]

By William Whitaker, B.A. (Lond.), F.G.S., of the Geological Survey of England.

ALTHOUGH the subject of this paper has already been discussed in detail,[1] yet, as this has been done from a medical rather than from a geological point of view, it may be well that the chief facts of the case, the method of investigation followed, and the conclusions come to, should be brought before the Geological Society; for the Society will not fail to have an interest in noting what a practical bearing our science has on the health, as it has long been known to have on the wealth, of mankind.

In 1865 my friend, Dr. Buchanan, was appointed by the Privy Council to inquire into the results of sanitary improvements in England. With this object he visited twenty-five large towns in which various works, designed to promote the public health, had been for some years in operation; and studied whether any change for the better, in the general health of the population, had taken place since the establishment of those works, and if so what that change was.

The result of this enquiry was published in the Report of the Medical Officer for 1866, and whilst showing, as was expected, that the death-rates from fever, cholera, &c., had been lowered, it also led to the quite unexpected conclusion that consumption had been very materially affected. This disease however had not decreased in all cases, and on examination it turned out that *the lowering of the consumption death-rate went along with the decrease of water in the subsoil by improved drainage,* but did not steadily go along with any other sort of improvement.

The most marked instance of this is Salisbury, where the death-rate from consumption, since the new drainage-works have been in use, is about half what it was before. Taking that death-rate, before the establishment of the sanitary works, at 100, the new rate is 51. The next town on the list is Ely, where, on the same principle, the new rate is 53, whilst at Rugby it is 57, at Banbury 59, at Worthing 64, at Leicester and Newport 68, at Macclesfield 69, at Cheltenham 74, at Bristol 78, at Dover 80, and at other towns there has been an improvement in less degree.

These figures, which are calculated from the death-rates over a number of years (as no safe conclusion could be come to from the statistics of a very short time) seem, when it is shown that no other sanitary work had any particular effect, to be conclusive as to the connection between land-drainage and consumption. They suggested to Dr. Buchanan that it might be well to see whether natural causes

[1] Report of the Medical Officer of the Privy Council for 1867, pp. 14–17, and 57–110. 8vo. London, 1868.

that affect the saturation of the subsoil had not also some connection with consumption; or in other words, whether places on those geological formations that allowed the free drainage of water would not have a lower consumption death-rate than places on less pervious or damper beds.

Dr. Buchanan having been commissioned to undertake a further enquiry, with the object of bringing new facts of this kind into evidence, application for the needful geological data was made by the Medical Officer of the Privy Council to the Director-General of the Geological Survey, and of course all the information in the possession of the Survey was placed at Dr. Buchanan's disposal.

After a little consideration we saw that it would be useless to take up for examination any district in which the surface-deposits of gravel, etc., had not been mapped, as well as the regular formations; and also that it would not do to take small areas scattered here and there about the kingdom: one large connected tract was essential for any trustworthy result. This at once limited the range of the enquiry to the South-East of England; for only in the counties of Kent, Surrey, and Sussex (or part thereof), had the Geological Survey mapped those surface-deposits (with some exceptions of no great importance here). There are other tracts—as in Lancashire—where the drift has been mapped, but they are of much smaller extent. This limitation having been made, I was instructed to give Dr. Buchanan all the help in my power, and consequently I worked with him for some little time, referring to my colleagues for information as to districts that were out of my own personal knowledge.

Luckily for the enquiry the aforesaid three counties have other recommendations. They are without any great manufacturing industry; and the conditions of life in factories had been proved, by previous investigations, to have an influence of their own upon the disease in question: they have great variety of soil, and yet their geological formations have, for the most part, a continuous outcrop, and often take up broad tracts; and they have many different conditions of surface, but without the level of the ground being subject to too abrupt changes, such as would be found in mountainous districts.

The metropolitan parts of Kent and Surrey had of course to be left out of consideration, as it would be quite hopeless to investigate a place like London, in which there are so many disturbing causes, such as the presence of large hospitals and the exceptional industrial conditions of the population.

It is needless for me to enter here into the purely statistical part of the enquiry, or the various allowances that had to be made for the influence of public institutions; for the influx of visitors to places supposed to be good for consumption; for wrong returns of the causes of death, &c.; enough to say that all these things were carefully taken into account by Dr. Buchanan.

The geological part of the enquiry was two-fold, embracing in the first place the consideration of the composition and character of the

formations of the three counties, and the description of the stratigraphical conditions and physical features of the 58 districts which supplied the statistical data; and, in the second place, being directed to an estimation of the number of people living on each formation. In the former of these the knowledge of my colleague, Mr. Topley, was made use of for part of the Wealden area; whilst Mr. Bristow gave some information on the southern edge of Sussex and Hampshire, a very small part of which latter county came within the bounds of Dr. Buchanan's work.

The geological formations of the South-East of England range from the Bagshot Beds down to the Hastings Beds, without any gap, the series being perfect. Besides these there are alluvial flats, both as broad marsh-lands and as narrow strips along streams; fringes of shingle and blown sand along parts of the coast: and a great number of tracts of Drift loam, gravel, and sand on all formations, at many levels, and of various sizes.

In working out conclusions from the data that had been got together it is clear that, as saturation of subsoil was the chief thing to be considered, the mere permeability or impermeability of a formation was not the only condition to be examined; but that the height and slope of the ground and the dip of the beds were important matters, as well as any other fact that bore on the water-holding power of the beds or their capacity for drainage in any district.

From the varying character of some of the formations (as for instance the Lower London Tertiaries, the Lower Greensand, and the Hastings Beds), great care had to be taken to avoid hasty generalisations, and a detailed consideration of each particular district was made needful, the same formation having different characters, and giving rise to different physical features and conditions in different parts.

Again, though a formation, as the London Clay, might be of the same character throughout the whole area, yet any generalisation at once founded on that fact might have been false; for it was soon found to be absolutely essential to consider how the country formed by such a homogeneous formation is modified by the occurrence of cappings of gravel, &c., districts of bare clay being practically quite distinct from those where the clay is covered by 10 or 20 feet of pervious gravel.

This detailed method of examination sometimes showed that large areas formed of like beds, and which at first sight might have been thought to be of like character, were really far from being so: thus the London Clay and the Weald Clay are both thick masses of impermeable beds of much the same composition, but the broad tracts over which they crop out are for the most part quite unlike. The differences between the two great clay-countries of the South-East of England are so many that perhaps they may be best shown when thrown into the form of a table, as below, from which it may be seen that, whereas the London Clay is so disposed as for the most part to allow of the flowing off of surface-water, the Weald

Clay is favourable for holding back the same, and therefore the districts formed by the two clays are quite different in this important particular.

Comparisons of the Districts taken up by the Outcrops of the London Clay and of the Weald Clay.

London Clay.	Weald Clay.
(1). Often covered by gravel, especially in the populous districts.	(1). Less covered by gravel.
(2). The capping of gravel is mostly of fair thickness.	(2). The gravel is comparatively thin, and often insignificant.
(3). Forms a comparatively high country (except in the gravel-flats bordering the Thames), and is not closely bordered by higher ground of other formations.	(3). Forms a low country, bordered on both sides by higher ground.
(4). Has, for the most part, a gently undulating surface (except for the gravel-flats).	(4). Forms a flatter country, less varied by undulations, and those of less height.
(5). With comparatively few rivers, and those almost wholly from its own drainage (except where the larger rivers flow directly across it, through valleys).	(5). Is a channel for many rivers, which carry off not only its own drainage, but also that of the higher ground on either side, and which meander over it for long distances, and with slight fall.

At first sight, and in a purely geological aspect, the general result of the enquiry might be summed up as follows: that the consumption death-rate varies roughly as the age of the formations (disregarding alluvium, gravel, &c., which are distributed pretty fairly over all): the districts of the Tertiary beds and the Chalk holding, as a rule, the highest place, that is to say having the lowest death-rate; those of the Wealden beds taking the lowest place; and those of the intermediate Greensand, &c., coming in the middle. But this would give a very illusive view, for there are many exceptions.

Two methods of analysis of the obtained facts were used by Dr. Buchanan. Firstly, grouping the registration-districts in their order of consumption death-rate, to see what proportion of the population, in each group, live on pervious or impervious soils. For this purpose fifty of the districts (the remaining eight being left out as having exceptional characters, and needing further examination) were classed in five groups of ten each, with the following result:—

Groups of Ten Registration Districts.	*Percentage of Population.*	
	On Pervious Soils.	On Impervious Soils.
1. With Lowest Consumption Death-rate ...	90·9	9·1
2. ,, Higher ,, ,, ...	87·7	12·3
3. ,, ,, ,, ,, ...	79·5	20·5
4. ,, ,, ,, ,, ...	79·2	20·8
5. With Highest Consumption Death-rate ...	64·2	35·8

These gross results, though at first sight more exact than the rough general result first given, are however open to many objections, one of the chief, in a geological point of view, being

that the physical features of the districts are not taken into account, and therefore the classification of the soils as pervious and impervious is in some cases delusive; for a very low-lying tract of pervious beds may, from its position, be saturated with water that cannot escape, and would therefore be in no better case, as regards the draining away of water, than a tract of impervious beds; indeed not so well off perhaps as a high-lying sloping tract of the latter kind.

The second method of numerical analysis adopted by Dr. Buchanan was calculated to lead to more exact and valuable results. Its plan was, to quote his own words, "to select out of the fifty-eight districts such as are most comparable with each other in regard of their position and geological structure, and to see how their phthisis is affected by the perviousness or imperviousness, elevation or lowness, slope or flatness, in the members of such more limited series," a method which involved various comparisons of districts and formations.

Firstly, as regards the amount of consumption on pervious soils from which water can drain away, compared with that on more impervious or retentive soils. The great tract known as "the Weald," contains within itself good materials for such a comparison, the districts that are chiefly on the more sandy and more sloping Hastings Beds contrasting with those on the flatter Weald Clay. In no case indeed is a district wholly sand or wholly clay, but the proportion of the population living on clay or on sand varies greatly; moreover many of the districts are partly on other formations. Parts where the Weald Clay is covered by gravel, being of an intermediate character, were treated as half pervious and half retentive. There were found to be fifteen registration-districts in which the greater part of the population lived on the various divisions of the Wealden series, and an examination of these showed that the districts with the higher consumption death-rates have the larger proportion of their population on retentive beds, and that those with the lower rates have the larger proportion on the more pervious beds; the numbers varying from 95 per cent. of the population on pervious, and 5 per cent. on retentive soils in the case of Hastings (which, after proper correction has been made for the influx of invalids, seems to be the second best district on the Consumptive Bill of Health), to 30 per cent. and 70 per cent. respectively in the case of Petworth, which is the worst district but two out of the whole fifty-eight.

Like results were got by the comparison amongst themselves of the ten districts in which the greater part of the population live on the Lower Greensand.

Secondly, a comparison was made between districts composed mostly of pervious soils at a fair height and with a good slope, in short in which there were good facilities for the draining away of water; and other districts of like beds, but which from their position and character were more liable to saturation. In this case the slope of underlying impervious beds is sometimes important, as a shallow

basin of sand or gravel on clay is favourable for the holding rather than for the flowing off of water. From this comparison, it was found that districts mainly on a set of pervious beds (whether of gravel over London Clay, of the sandy and pebbly Lower London Tertiaries, of Chalk, or of Lower Greensand) and which have a fair general height, and a fair slope of surface, have a lower consumption death-rate than other districts on the same formations, but at lower levels, and with flatter surfaces.

There is one remarkable kind of exception to this rule. It is that the low-lying tracts of shingle bordering the shore, and saturated more or less by sea-water, seem to be not badly off in respect of consumption,—Dover, where a large part of the population live on shingle, being a notable case in point.

Thirdly, districts chiefly of impervious formations were examined with regard to their physical features; the higher and more sloping, which allow of the flowing off of surface-water, being compared with those that are lower and flatter, and on which therefore water rests longer. This of course was little more than a comparison of the two great clay-tracts, those of the London Clay and of the Weald Clay, the physical differences of which have been noticed before (p. 502).

The gravel-covered London Clay ranges itself amongst the pervious formations, but a comparison of the two clays when bare shows a great difference in their consumption death-rate. Many districts have a goodly proportion of their population on the sloping London Clay without their consumption being much affected, whereas in those that have much population on the flat Weald Clay the death-rate is high; so that here again wetness and consumption go together.

The few exceptions are perhaps one of the best proofs of the rule. On those parts of the South Coast where a large population lives on London Clay the consumption is very high,—Chichester indeed standing worst of the fifty-eight districts. Now in that country the London Clay has not its usual features, but forms a more or less gravel-covered, low-lying, water-logged flat, being (exceptionally) much in the usual condition of the Weald Clay.

As the shingle-tracts bordering the sea seem to be an exception to the rule that low-lying pervious beds are much worse off than those at higher levels; so the alluvial flats bordering the sea seem to form an exception to the rule amongst impervious beds, the striking case being Sheppey, which stands at the head of the whole fifty-eight districts, although the greater part of its population live on alluvium, close to the sea, and at about the sea-level. One is led to think therefore that saturation by sea-water and saturation by fresh-water are quite different matters, and that whereas the latter increases the consumption death-rate, the former is comparatively harmless, or perhaps even beneficial. Sea air too may be good for consumptive patients.

The conclusions that result from the geological and statistical

examination of the counties of Kent, Surrey, and Sussex, of which an outline has been given above, are as follows :—

(1). *That on pervious soils there is less consumption than on impervious soils.*

(2). *That on high-lying pervious soils there is less consumption than on low-lying pervious soils.*

(3). *That on sloping impervious soils there is less consumption than on flat impervious soils.*

(4). These inferences must be put along with the other fact, that *artificial removal of subsoil-water, alone, of various sanitary works, has largely decreased consumption.*

From which follows the general inference, that WETNESS OF SOIL IS A GREAT CAUSE OF CONSUMPTION, no other condition having been found, in the course of these inquiries, to go along with the consumption death-rate to any great extent.

The value of such a conclusion, should it stand the test of further examination, cannot I think be over-estimated. It would introduce a new principle and object into the carrying out of those drainage-works that have been so much called for of late; it would aid consumptive people in choosing healthy living-places, and in avoiding those that may be hurtful; it would lead to the lessening of a disease that is the special curse of our country; and, by bringing men of science something nearer to the knowledge of the first cause of consumption, it might lead to the discovery of that cause, and of such treatment and remedies as would successfully grapple with the disease.

Confirmatory and independent evidence of the truth of the above conclusion comes to us from America, Dr. Bowditch having drawn attention, in 1862, to the fact that "medical opinion in Massachusetts . . . . tends strongly to prove . . . . the existence of a law in the development of consumption in Massachusetts . . . . that dampness of the soil . . . . is intimately connected, and probably as cause and effect, with the prevalence of consumption."[1] The Registrar-General for Scotland, quoting the above (in his Seventh Annual Report), and applying it to eight large towns in Scotland, accepts the theory. It is right to add however that no such detailed examination, as in our case, seems to have been made in either America or Scotland.

[1] "Consumption in New England and elsewhere, or Soil-moisture one of its chief causes." Ed. 2. Boston, 1868. I should state that Dr. Buchanan did not know of this pamphlet until the completion of his own researches.

STEPHEN AUSTIN, PRINTER, HERTFORD.